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Lighting Design as a Universal Design Strategy to Support Functional Visual Environments

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Abstract. The visual environment that surrounds us all makes us able to understand and interpret the world we live in. One of the most important players in that field is light. In general, it is useful for all of us to have aesthetic, appropriate and well-functioning lighting conditions. Research has shown that when it comes to visually impaired and hearing-impaired people it is of crucial importance in order to make their daily lives work and being self-reliant. Based on this research rules and regulation in a Danish context is studied to see how lighting design can support Universal Design in general and the specific users need in particular as described in the user organisations guidelines to accessibility. The regulations often focus on the quantitative aspects like light levels and the uniformity of the light. They certainly are important aspects however, they are not sufficient for users with specific needs. This point to the need for a broader approach to lighting design where the quantitative aspects meet the qualitative in order to fulfil a successful Universal Design of the visual environment. This paper present a general discussion on lighting design strategies and their impact on aesthetics and functionality of the visual environment based on classic theories on lighting design describe by Richard Kelly, William M. C. Lam and Hervé Descottes. These strategies are put in relation to the overall concept of the Universal Design principles and the guidelines outlined by The Danish Association of the Blind to support a visual stimulating environment.

Keywords. Lighting design concepts, visual environment, accessibility, lighting standards, visually impaired

1. Introduction

In the Convention on the Rights of Persons with Disabilities, "Universal design" is defined as design products, environments, programs and services that allow all people to the greatest extent possible to participate equally in the society [1].

Though the convention stresses the need for considering the needs of all users, the interpretations in national regulations and guidelines often emphasize the functional needs of e.g. the walking-impaired, whereas the needs of the sensory impaired such as the visually or hearing impaired, get less attention, at least in the Danish context [2]. When it comes to the needs of the visually impaired regarding light, they are met with answers addressing quantitative aspects such as the amount of light measured in lux, while only few of the qualitative aspects of lighting are described [3].

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This paper takes its point of departure in *sight* and how *light* supports seeing [4]. Sight is one of man's five senses and as we receive the majority of information about our surroundings through this sense, a well-lit visual environment is important. It is important for people in general and even more so, when it comes to visually impaired people, who are enabled to use their remaining sight all the better, as well as the hearing impaired as they depend on the visual environment for lip-reading.

The Danish Association of the Blind has made a detailed guideline as part of the Universal Design strategy for visually impaired people, which describes the lighting qualities that are important when designing an environment accessible for the visually impaired. Based on research as well as experience, the guideline points out both quantitative and qualitative requirements [5], as well as the qualities of light that enable the visually impaired person to understand spaces and their form. In comparison, e.g. the Danish Building Regulation only has a few requirements regarding the visual environment, covering only a small part of the needs of the visually impaired people [6].

Unlike the Building Regulation, lighting designers - like the visually impaired themselves - often focus on the visual environment. Therefore, it is relevant to study lighting designers' approaches to the design of the visual environment to see whether there is a correspondence between the design measures proposed by designers and the needs that the visually impaired themselves describe. Even though lighting design is often spectacular, focusing on the highlighting of a specific event or a particular function, the main task is to create a well-lit environment. Thus, this paper intends to discuss to what extent professional international lighting design theory can support visually impaired people's needs through addressing the visual environment as part of a Universal Design strategy. Thereby, we may take a first step into a critical discussion on Universal Design and the planning of the visual environment.

The paper compares three lighting design theories respectively by W. Lam, R. Kelly and H. Descottes to the specific elements of the user organisations' guidelines to a supportive visual environment. Six aspects are extracted from the guideline and then compared to the lighting design theories. The selection criteria of the three lighting design theories are 1) their having an international reputation; 2) their having been applied in the practice of lighting design; and 3) their appearance in the curriculum of the international Lighting Design education at Aalborg University.

2. Three Lighting Design Theories

The Danish Building Regulation states that, in general, artificial light has to follow the European standards [6]. When it comes to visually impaired people, the regulations indicate three aspects to fulfil:

- The light must serve a guiding function
- The light must underline important entrances and shared access ways
- The light must be without glare

The Danish guideline for visually impaired people, on the other hand, is far more specific and highlights six main aspects [5], which are important when creating a supportive visual environment:

- Luminance (candela per square meter, cd/m²)
- Form and shadow pattern
- Glare (disability glare and discomfort glare)

- Illuminance (lux level)
- Colour temperature (Correlated Colour Temperature/CCT, measured in Kelvin)
- Colour rendering (Colour Rendering Index/CRI, or Ra index)

Luminance describes the amount of light flowing in a particular direction from a surface [7]. Luminance is measured in candela per square meter (cd/m^2). Luminance describes the experienced brightness of a surface. The guideline describes luminance in relation to adaptation and contrast, which emphasises that the experience of luminance is relative and depending on the brightness of the surrounding surfaces and their correlation.

Form and shadow pattern are described in relation to our ability to distinguish the shape of an object [8]. The guideline emphasises the importance of achieving a balance between the bright and the dark side of an object and the direction of the light onto that object to reveal its shape as clearly as possibly [9]. There is no term for measuring this ability, rendering it solely dependent on a personal assessment. The guideline stresses this qualitative aspect of the visual environment.

Glare is described through the concepts of disability glare and discomfort glare [10]. The guideline argues for avoiding glare as much as possible, as glare reduces vision.

Illuminance is the luminous flux falling on a surface, and it is measured in lux [11]. The luminous flux or a beam of light is not visual to the human eye. According to the guideline, the variation of illuminance in a room and on objects is very important and just as significant as the actual lux level, meaning that the relation between quantity and quality is crucial.

Colour temperature describes the colour tone of the light; whether it is warm, neutral or cold. The correlated colour temperature (CCT) is measured in Kelvin [12].

Colour rendering indicates the capability of the light source of 'realistically' rendering the colour of an object. The capability is listed in a Colour Rendering Index (CRI) or Ra index [13]. The guideline stresses the importance of a full spectrum light source capable of rendering all colour nuances, as the recognition of a colour helps understanding what one sees.

The most characteristic trait in the description of each of the six parameters is that qualitative aspects are underlined rather than quantitative ones. The Danish guideline for visually impaired people and the three lighting design theories presented in the paper at hand do not follow the same scheme, each having their own individual approach. Therefore, the aspects described in the Danish guideline are not necessarily found in exactly the same form in the three design theories. Rather, these aspects are addressed either directly or indirectly through various related approaches.

In the following section, each of the three lighting design theories are described shortly and compared to the Danish guideline to point out how, if at all, these theories address the six main aspects or parameters stressed by the guideline.

2.1. Richard Kelly: Lighting Design as an Integral Part of Architecture, 1952

The lighting theory of Richard Kelly is the oldest of the three. It is presented in an article for the American magazine College Art Journal [14]. Here, Kelly introduces a very simple design strategy stating that a lighting design should have three elements of light effect: focal glow or highlight, ambient luminescence or graded washes, and play of brilliants or sharp details. Later in the text, Kelly explains what the three different effects

are related to: "*These three kinds of light, (1) Focal glow, (2) Ambient luminescence, (3) Play of brilliants, respectively (1) make it easier to see (2) make surroundings safe and reassuring and (3) stimulate the spirit*" [15].

This means that the first effect, *Focal glow,* ensures the variation in both illuminance and luminance, thus highlighting elements of a space and guiding the user of a room in the right direction. This aspect touches upon the shadow pattern that the variation in light levels will produce. The second effect, *Ambient luminescence*, provides to a space the sufficient light level for orienting oneself, this meaning that the level of illuminance is in focus here together with the distribution of the light. The third effect is the *Play of brilliants*, which increases the variation of light even further, meaning that this effect creates glare. Glare is often discussed in relation to its negative effects, being seen as the source of visual problems, but Kelly sees in it a positive effect to the space. The spectral colour of light - cold or warm - is discussed in relation to the question of how human skin is most accurately rendered in different contexts.

Throughout the article, Kelly describes the different characteristics of light, trying to establish a vocabulary for the study of the visual environment in relation to lighting design. His approach is related to his experience of light and not to the different existing regulations or guidelines. He argues for a balance between the three different light effects in order to obtain a bout beautiful and comfortable visual environment. Kelly does not translate these effects and their measurement into numbers or values, but, rather, argues that one should work with light as *"visual imagination as the cause for visual experience in sense perception*." [16].

Of the six aspects described in the Danish guideline, five of them are addressed in his theory. Only the aspect regarding colour rendering is not mentioned. The focus is on light as experienced, placing the human eye in the centre of the theory. Even though this theory of lighting design is described through only three effects, it covers very well the main parameters of the Danish guideline for visually impaired people. However, Kelly's theory is without scientific references and he only refers to his own practise and long-time experience of working in the field of lighting design.

2.2. William M. C. Lam: Perception and Lighting as Form-givers for Architecture, 1977

Already as a new teacher in lighting design, Lam started questioning the focus on standards and the many quantitative terms related to them, asking if, "*… a good luminous environment [could] be defined meaningfully in purely quantitative terms*..." [17]. This is to some extent the driver of his work throughout his career where he repeatedly questions the quantitative aspects of lighting design. He sums up his focus on the experienced visual environment in a new set of design criteria, which he names *Biological needs for visual information* [18].

Lam is interested in how our visual system acts, as perceived in traditionally theory on perception, which is the most important function in order to make meaning out of what we receive of visual stimuli [19]. He argues that lighting design, when seen in relation to visual perception as described in traditional theory on perception, must consider seven factors in the lighting design phase. The seven factors are related to illumination and traditional lighting design processes [20]. Throughout his book, Lam highlights that lighting design practice is an interdisciplinary effort inspired by engineering, psychophysical research, psychology and architecture. He is very critical towards the traditional design process, which he thinks too often results in lighting design being "…boringly repetitive, wasteful and frequently even confusing" [21]. Lam,

therefore, wants to restructure the design process in order to maximise communication within the design team to create a relevant, comfortable and well-integrated lighting design [22]. He sums this up in 22 rules of thumb [23], which mainly focus on the architectural design rather than the actual visual environment.

In the lighting design theory of Lam, five of the six aspects mentioned in the Danish guideline for visually impaired are addressed. The only aspect missing is colour rendering. Lam is interested in human vison and perception, and he stresses that lighting design has to relate to the human eye and the way in which we perceive light, stating that "[a] good luminous environment helps us to do what we want to do and makes us feel good while we do it" [24]. Later in his book, he continues by saying that " …in addition, we need to accentuate the positive aspects of the luminous environment, by providing lighting natural and relevant to activities and expectations, giving orientation clues, creating a focus on activities, and providing interesting visual rest centres, without simultaneously introducing glare or unwanted distractions" [25]. These statements relate very well to the Danish guideline for visually impaired people. Furthermore, they can be understood as part of a Universal Design approach which seeks to make as many people as possible benefit from a well-designed visual environment. Unfortunately, Lam's theory focuses on architectural design rather than the actual visual outcome of the lighting design, and therefore does not deal with addressing specific qualities of light.

2.3. Hervé Descottes: Architectural Lighting: Designing with Light and Space, 2011

Descottes introduces six visual principles on which he bases his lighting design theory. The principles are illuminance, luminance, colour and temperature, height, density, and direction and distribution [26].

Like the two other lighting design theories mentioned above, Descottes' theory deals with the matter of how the human eye is built and the role it plays for how we perceive light [27]. He focuses on the anatomy of the eye, on how light enters the eye, and thereby creates the image of our environment.

He states that it is important to be aware of the qualities of light and keep questioning the standards and regulations of lighting design. He argues that the purpose of his efforts is not just to create a lighting design with as much light as possible but to ask "how little light can be put on for maximum effect" [28].

He seeks to present the concept as simply as possible and describes the effect of a well-composed lighting design by stating, "[w]hat we perceive as three-dimensionality is simply patterns of brightness and darkness juxtaposed against one another" [29].

Descottes describes visual aspects and highlights their importance, and he places the qualitative approaches over the quantitative, aligning himself in that respect with the approach presented by the Danish guideline for visually impaired people.

Descottes includes all six main parameters of the Danish guideline in his theory though de does not present them in the same order and does not emphasize the same aspects. Though he addresses the aspects and the qualities of light, the illustrations and diagrams reveal a missing sense of the untapped potential of light for creating a supportive visual environment. This is very clear in the illustrations of the shadow pattern [29], where he stresses the 'special effects' of lighting rather than addressing the actual form-enhancing qualities that a well-balanced shadow pattern may offer to everyday users of buildings and spaces.

When all six aspects of his lighting design theory are addressed by designers, he states, a fundamentally enhanced experience of architecture is made possible:

"Ultimately, the best lighting in architecture simply evokes an atmosphere, an emotion; a memory of a space in time inextricable from the architecture's very being"[30]. This is a very poetic way of expressing his lighting design theory. It indicates that when it comes to the final output of the lighting design, Descottes is more interested in the ability of light to create a certain social or aesthetical atmosphere than in the ways in which lighting design may enhance vision and support the understanding of space and form - and thus address the specific needs of e.g. the visually impaired.

Table 1. Overview of how the six guidelines from the Danish association of the Blind is outlined in the three lighting design theories.

	LIGHTING DESIGN THEORIES		
	Richard Kelly	**William M.C. Lam**	**Hervé Descottes**
GUIDELINES By the Danish Association of the Blind			
Luminance (Cd/m²)	Describes the qualities of contrasting various kinds of light to create visual beauty and comfort. Described through the concept of *Focal glow.*	Describes the qualities of variation in luminance according to task performance. Relates the variation in luminance to contrast.	Describes the luminance as an element to create a sense of hierarchy and direction to space, and to accentuate depth in a space.
Form and shadow pattern	Describes the impact of diffuse light and the direction of light. Described through the concepts of *Focal glow* and *Ambient luminescence*.	Describes how specification of high quality perception of three-dimensional objects, can affect the impact of the shadow as a form-enhancing tool. Illustrated by photos.	Describes how specification of direction and distribution of light, san affect the impact of the shadow. Illustrated by photos.
Glare	Describes the complexity of glare and how it can have an interesting and positive effect on a space. Described through the concept of *Play of brilliants.*	Describes how discomfort glare has to be avoided. Underlines the difference in character of glare and sparkle.	Describes how discomfort glare has to be avoided but emphasizes that controlled glare and sparkle can add visual qualities to a space
Illuminance (lux)	Describes how a well-composed level of light can have a positive impact on the perception of a space. Described through the concepts of *Focal glow* and *Ambient luminescence*.	Underlines that it is not only a matter of quantity of light but also the quality of light (source concentration, direction, contrast) that affects the experience of the visual environment.	Describes how sufficient illuminance create visibility but underlines that a careful control of illuminance level in a space is crucial.
Color temperature (CCT)	Describes the preferences of cold or warm light in relation to the color of daylight at different times of the day.	Underlines the different approaches by describing the color temperature either through the laws of physics or through perception.	Describes how color temperature can have an effect that create identity and orientation. And in addition, how it has a relation to our circadian rhythm.
Color rendering (CRI or Ra Index)	Not included.	Not included.	Describes the technical aspects of CRI.

3. Discussion and Conclusion

When comparing the guidelines from the Danish Association of the Blind with the three lighting design theories, we found that they all focused on the visual environment and on achieving a broad knowledge of how vision and light interact. All three lighting design theorists make vision their point of departure and therefore the visual environment is a central aspect of their approach and all reveal a profound knowledge of how light and vison interact. They all emphasise that a well-lit visual environment is primarily based on the qualities of light rather than its quantity, as do the Danish guidelines for visually impaired people. However, none of the presented theorists seems to focus at any time on the potential of lighting design in creating visual environments based on the theory and goals of Universal Design.

Even though lighting design often looks rather spectacular, adding 'special effects' rather than supporting the form and - thereby - the use of a space, the three theories in question here are, in fact, based on considerations on how vision functions and how we experience and use lighting.

The three approaches focus on the perception of surroundings and things/objects and, thereby, on issues addressed by 5 out of the 6 aspects mentioned in the guideline from Danish Association of the Blind. In that sense, they are supportive in general of the recommendations of the Danish guideline, the main objective of which is to make surroundings accessible for all users. Thus, visually impaired people would probably benefit from lighting designs based on either of the three theories. The lighting design theories, thereby, express an interest in creating lighting designs that relate to vision and the human perception of light, rather than merely fulfilling the quantitative requirements of lighting standards. Nevertheless, when looking deeper into the theories, they all reveal a tendency, mirrored in current society, towards eye-catching and spectacular lighting designs, which overrules ambitions of creating delicate visual environments which support vision and usability. Knowledge of how to achieve well-balanced luminance and form-enhancing shadow patterns, it would seem, is not currently in high demand.

However, though all three lighting design theorists include the qualitative and quantitative aspects described in the guidelines published by the Danish Association of the Blind, their focus is somewhat different from that of the latter. Descottes sees the qualities of light as tools in the creation of the spectacular and atmospheric, Lam focusses on the building process and the building structure rather than the actual interplay between light and form. And Kelly focusses on the variation of light and lighting qualities rather than on the interplay between light and form and on how investigating the qualities of light is paramount to understanding form and space.

Both professional lighting designers and visually impaired people focus on the visual environments and the perception of our surroundings. This shared focus on the visual environment makes professional lighting design strategies interesting to the visually impaired.

In conclusion, the presented lighting design theories on the one hand and the Danish Association of the Blind on the other have convergent interests in enhancing visual environments. Therefore, such theories maybe inspiring and helpful to look into when planning and creating a lighting design for visually impaired people. However, when it comes to the final conceptualization and implementation of a lighting design, lighting designers often focus on creating spectacular effects rather than on enhancing the possibilities of the visually impaired to see and explore their environment in a satisfying

way. The promotion of a Universal Design strategy for lighting designs, then, is still a highly relevant issue.

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